TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 371

EXPERIMENTS WITH AN AIRFOIL MODEL ON WHICH THE BOUNDARY LAYER IS CONTROLLED WITHOUT THE USE OF SUPPLEMENTARY EQUIPMENT

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Summary

This report describes tests made in the Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics to determine the possibility of controlling the boundary layer on the upper surface of an airfoil by use of the low pressure existing near the leading edge. The low pressure was used to induce flow through slots in the upper surface of the wing. The tests showed that the angle of attack for maximum lift was increased at the expense of a reduction in the maximum lift coefficient and an increase in the drag coefficient.

Introduction

It is well known that the boundary layer on the upper surface of an airfoil grows thicker as the angle of attack is increased. The thickening and loss of energy continue until the boundary layer has insufficient energy to overcome the adverse pressure gradient, and reversal of flow and separation may occur, accompanied by an increase in drag, and finally by a reduction in lift.

Many attempts have been made to delay the separation either by removing the boundary layer by suction (References 1 to 5) or by adding energy to the layer by blowing air from the interior of the wing out through backward-opening slots in the upper surface (References 5 to 7). Some of these attempts have been successful in that the maximum lift coefficient or the angle of attack for maximum lift, or both, has been increased. Most of the methods employed, however, necessitate the use of mechanical devices, such as blowers, independent of the wing itself, and consequently they have had little application.

This report describes tests to determine the possibility of delaying the separation by use of the low pressure existing near the leading edge. Preliminary tests, which were made in 1926, indicated that air could be sucked through slots in the upper surface into the interior of the wing by the action of a discharge slot located in the low-pressure region on the upper surface near the leading edge. An airfoil of this type will be called an internal-circulation airfoil in this report. A model was constructed in 1927 but the tests were unavoidably delayed until 1930 when force tests were made of the model in the Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics.

Apparatus and Tests

A wooden, internal-circulation airfoil model (Figure 1) was constructed with the U.S.A. 35-A section (Reference 8), a span of 32 inches, and a chord of 8 inches. Slots were arranged in the upper surface of the model as shown in Figure 2.

The model was tested in the Variable Density Wind Tunnel (Reference 9) as reconstructed with a closed throat (Reference 10). The tests were made at a Reynolds Number of about 3,200,000. When first tested the surface of the model was much rougher than is usual for tests in this tunnel. The model was then shellacked and rubbed to produce a smoother surface, and retested. A test was made also with slots numbered 2 to 9, inclusive (Figure 2), covered with a thin sheet of paper doped to the surface of the model.

Results and Discussion

The results of the tests with all slots open are given in Figure 3, and those with some of the slots closed are given in Figure 4. The lift and drag coefficients, center of pressure, and ratio of lift to drag are plotted against the angle of attack. The results are given for the geometric aspect ratio of 4 and are not corrected for tunnel wall interference.

The results of tests of an unslotted, polished, metal model of the U.S.A. 35-A airfoil at a Reynolds Number of 3,520,000 (Reference 11) are plotted in Figure 5. This normal model had a

30-inch span and a 5-inch chord, but the results have been corrected to the conditions represented by a model with a 32-inch span and an 8-inch chord in a closed-throat tunnel with a diameter of 5 feet. The results are therefore comparable with those for the internal-circulation model. As compared with the normal model, the internal-circulation model with all slots open has approximately a 50-per cent larger useful range of angle of attack, an 18-per cent lower maximum lift coefficient, an 81-per cent higher minimum drag coefficient, and a 33-per cent lower maximum $\frac{L}{D}$. As compared with the normal model, the internal-circulation model with some of the slots closed has approximately a 21-per cent smaller useful range of angle of attack, a 9-per cent lower maximum lift coefficient, a 71-per cent higher minimum drag coefficient, and a 23-per cent lower maximum $\frac{L}{D}$.

Figure 3 shows that there was an appreciable improvement in the characteristics of the internal-circulation model after refinishing, although the surface was still much rougher than that of the normal metal model. This improvement indicates that a smooth model would have better characteristics than the one used in these tests.

The results of the test show that the useful range of angle of attack for this internal-circulation airfoil is much larger than for the normal airfoil. In this test the efficiency of the airfoil was impaired, but, if the slots are properly proportioned and located, it may be possible to increase the useful range of angle of attack by this method without lowering the efficiency of the wing to such an extent as to make it impracticable. An investigation should be undertaken to determine the number, location, and size of the slots to produce the most desirable characteristics.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 28, 1931.

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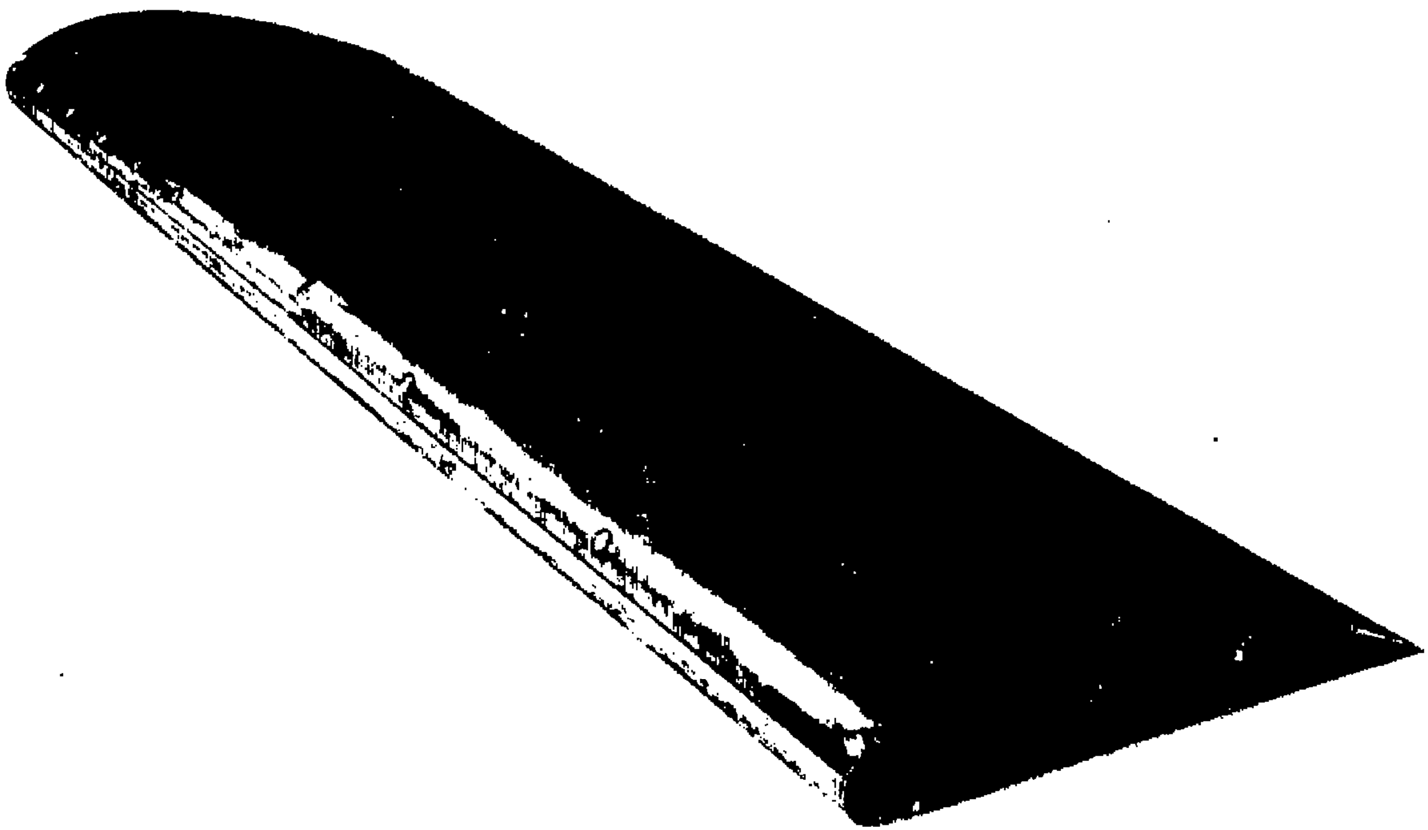
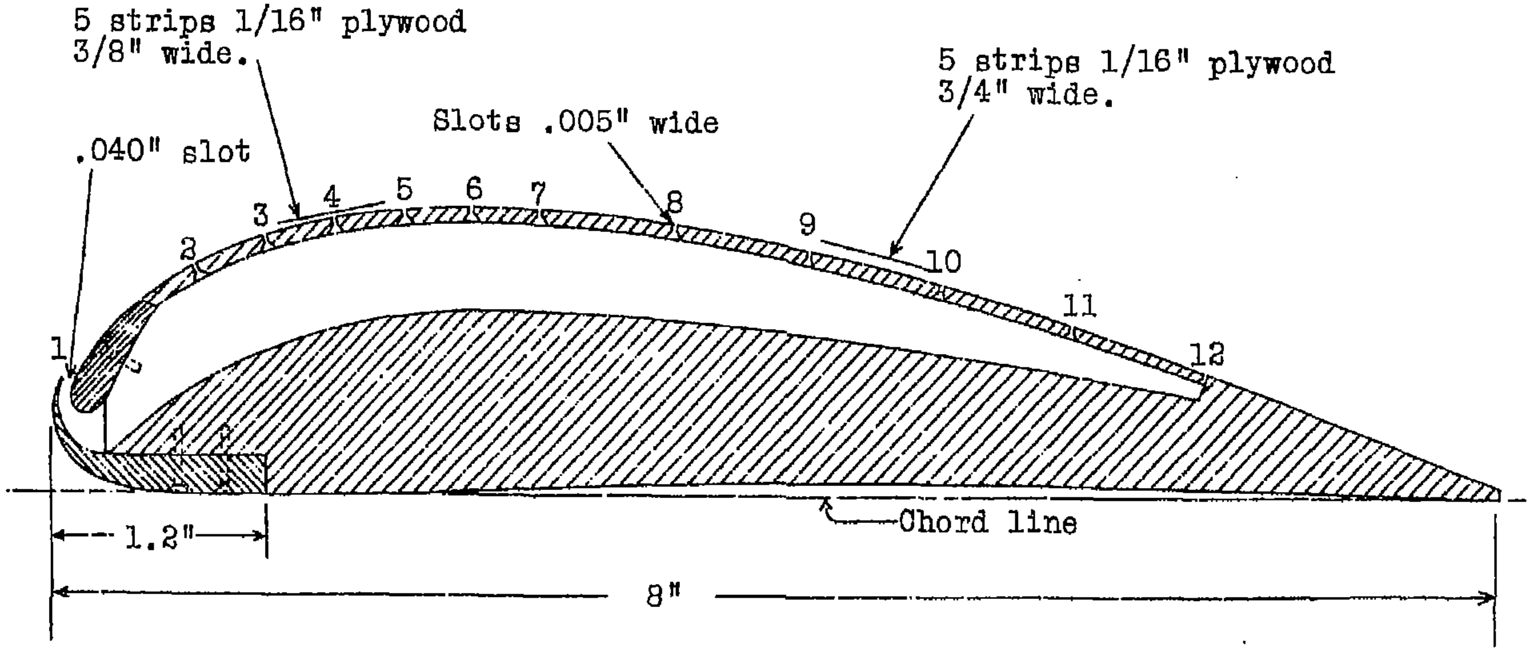


Fig.1 Internal-circulation airfoil model.



Airfoil section U.S.A.-35A

Span 32 inches

Fig.2 Internal-circulation airfoil.

Name of section: U.S.A. 35-A internal-circulation airfoil.
Size of model: 32 inch span. 8 inch chord. Date 9-12-30.
Pressure in standard atmospheres: 12.3 Test V.D.T. 473-4
Reynolds Number 3.2×10^6

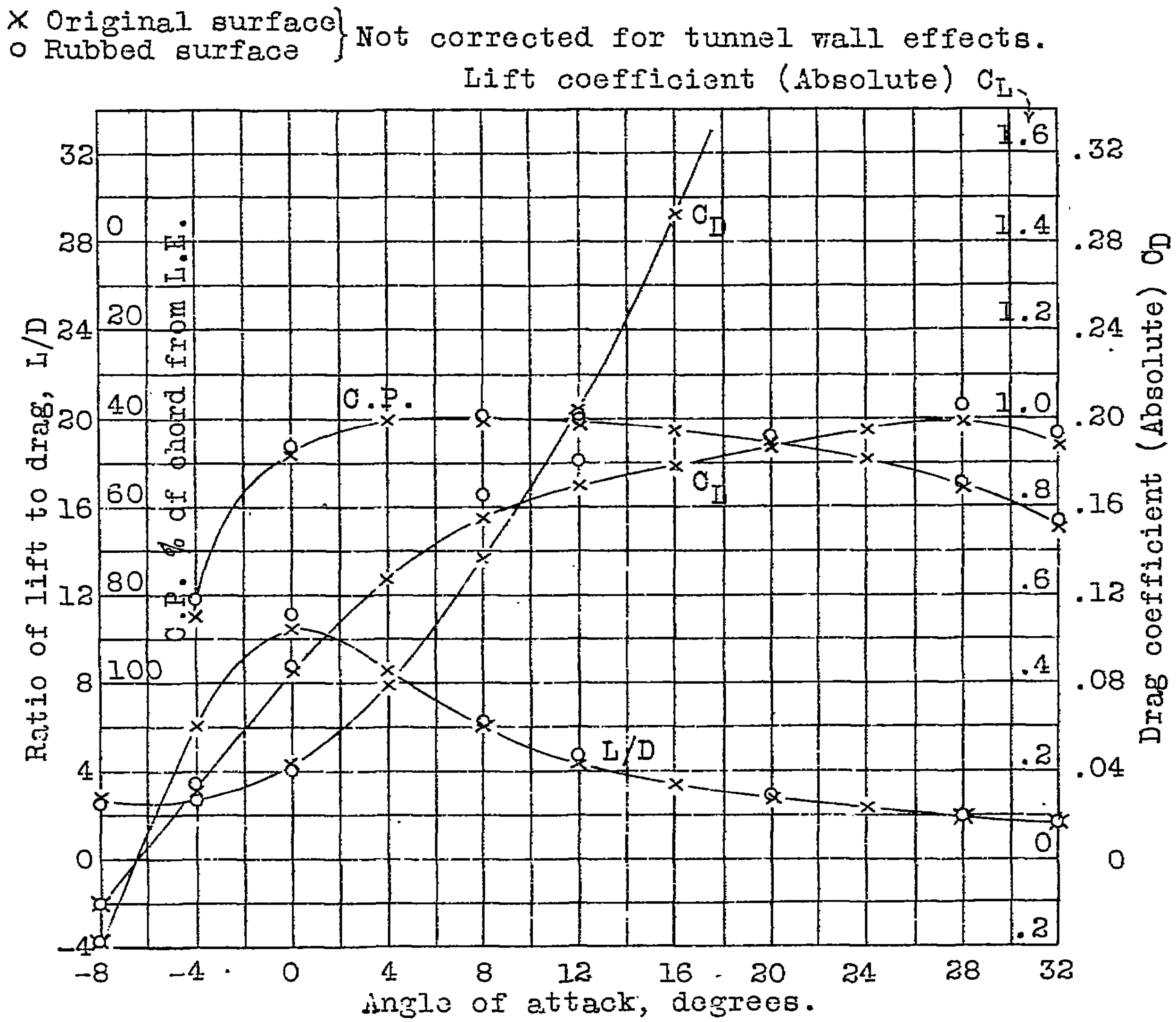


Fig. 3 Characteristics of the U.S.A. 35-A internal-circulation airfoil model with all slots open.

Name of section: USA-35A internal-circulation airfoil.
Size of model: 32 inch span. 8 inch chord. Date 9-12-30
Pressure in standard atmospheres: 12.3. Test V.D.T. 475
Reynolds No. 3.2x10^6

Not corrected for tunnel wall effects.
Slots number 2,3,4,5,6,7,8 and 9 closed.

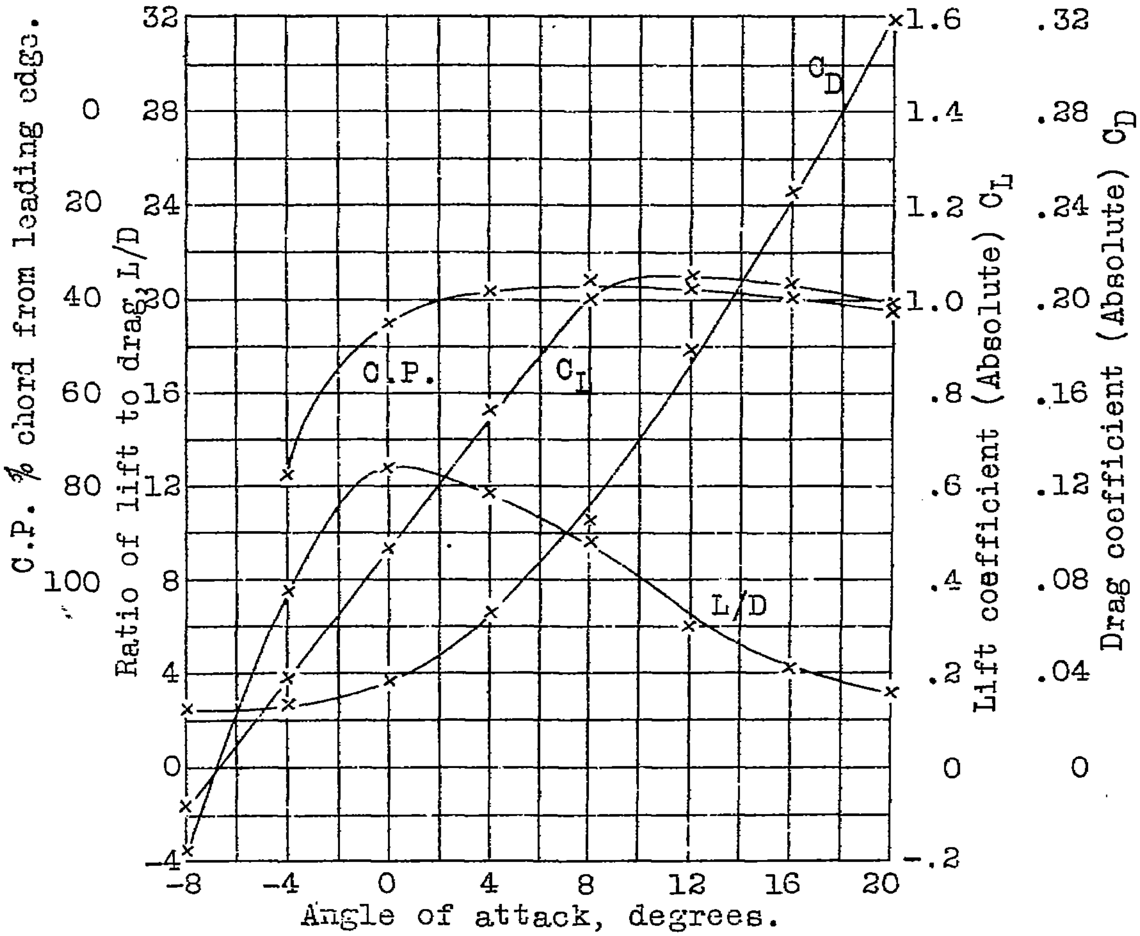


Fig. 4 Characteristics of the USA. 35-A internal-circulation airfoil model with slots 2 to 9 closed.

Name of section: U.S.A. 35-A
Size of model: 30 inch span. 5 inch chord. Date 2-4-25
Pressure in standard atmospheres: 20.3. Test V.D.T. 105-4
Wind velocity in ft. per sec.: 75.8 Reynolds Number 3,520,000

Corrected to following conditions: Model of 32 inch span and 8 inch chord in 5 ft. dia. closed-throat tunnel.

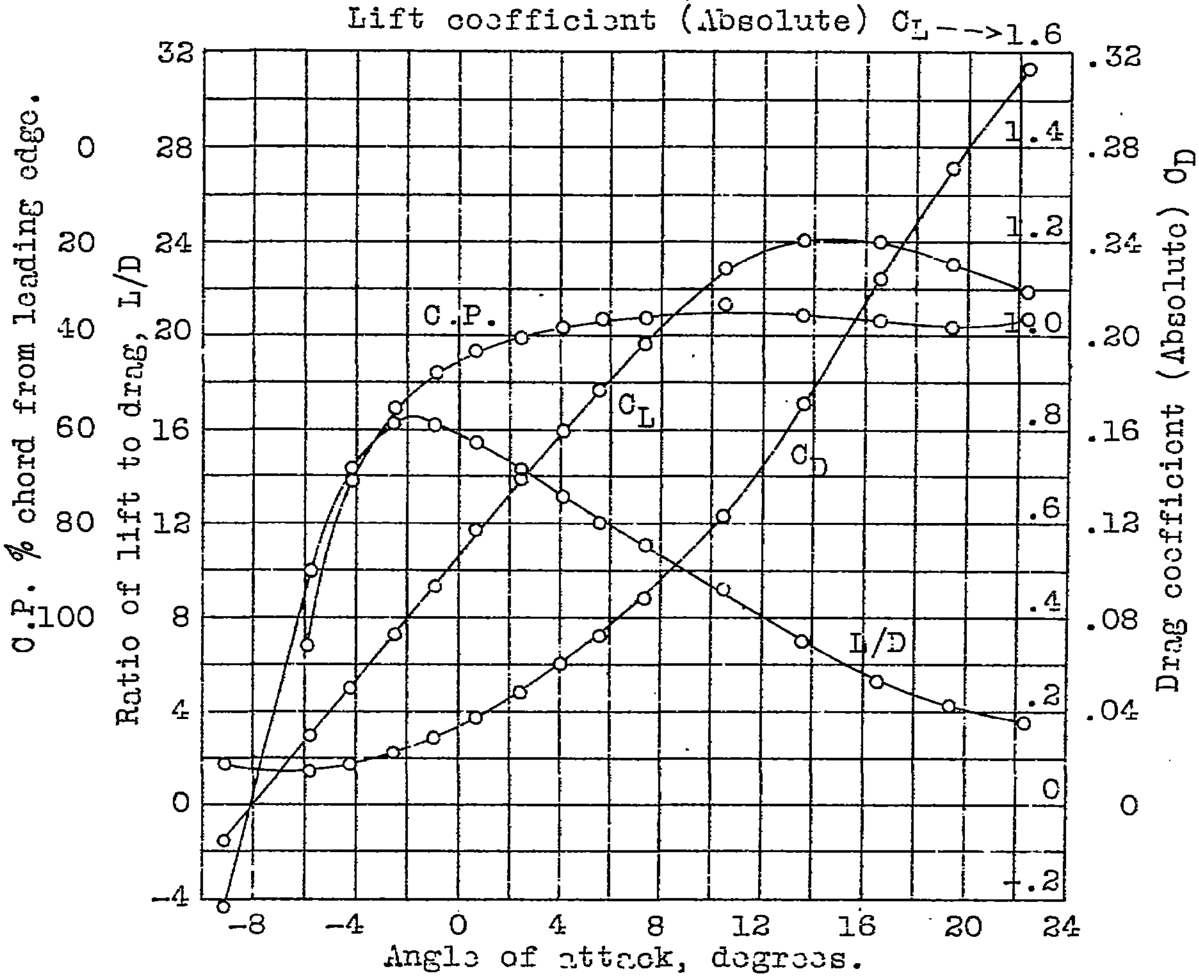


Fig. 5 Characteristics of an unslotted, metal model of the U.S.A. 35-A airfoil.